

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

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Application of

**ECHOSTAR COMMUNICATIONS CORPORATION,
GENERAL MOTORS CORPORATION,
HUGHES ELECTRONICS CORPORATION**

Transferors,

and

ECHOSTAR COMMUNICATIONS CORPORATION

Transferee,

For Authority to Transfer Control

CS Docket No. 01-348

**DECLARATION OF DR. RICHARD J. BARNETT
ON BEHALF OF
ECHOSTAR COMMUNICATIONS CORPORATION, GENERAL MOTORS
CORPORATION, AND HUGHES ELECTRONICS CORPORATION**

Executive Summary

This Declaration addresses the technical arguments raised by NRTC, NAB and Pegasus in their recent Petitions in this proceeding.

Those Petitioners have attempted to show that both EchoStar and DIRECTV, operating as individual companies, could technically implement satellite systems that would provide local TV programming to all 210 DMAs without utilizing an unacceptably large number of their licensed full-CONUS DBS frequencies.

The claims made by these Petitioners are flawed for the following reasons:

1. Their capacity calculations rely on improvements in technology that are either (a) not yet available and unlikely to become available in the near future, or (b) impractical from a business perspective because they would require all subscribers to transition to new set-top boxes. Each of the proposed technological developments is addressed in this Declaration;
2. The new satellite designs that they propose are superficial concept designs only and have not been rigorously developed to establish their feasibility, cost, schedule or performance. In fact several key aspects of these satellite concept designs are demonstrated in this Declaration to be seriously in error to the point that they are simply not feasible. All predictions of capacity achieved and spectrum used by these new satellites are therefore seriously in error;

3. They do not give sufficient consideration of the need for more national programming channels in the future to allow for new types of services (such as HDTV) or expansion of existing services. They instead are intent on trying to demonstrate the capability to provide local TV programming at the expense of the future of national programming.

I. Qualifications

1. My name is Richard Barnett. I am the President of Telecomm Strategies L.L.C., a Maryland company providing engineering consultancy services to a wide range of satellite projects and for many clients throughout the world. The principal consultants in the company, including myself, are all qualified engineers, and the company specializes in the technical design and technical regulatory aspects of satellite projects. My own personal experience is in the field of RF engineering, satellite communications system design and international satellite regulatory analysis. I have been working in the field of Direct Broadcast Satellite ("DBS") design since the early 1980s. My resumé is given in Appendix 1 of this Declaration.

II. Purpose and Scope of Statement

2. I have been retained by the Applicants to review and comment on the technical aspects of the Petitions received in the EchoStar/Hughes merger proceeding. In particular I have focused on the Petitions received from NRTC, NAB and Pegasus, which are the only ones with significant technical content.^{1,2,3} These three Petitioners have appended technical declarations to their petitions from Walter Morgan (for NRTC) ⁴,

¹ Petition to Deny by the National Rural Telecommunications Cooperative, February 4, 2002, CS Docket No. 01-348.

² Petition to Deny of National Association of Broadcasters, February 4, 2002, CS Docket No. 01-348.

³ Pegasus Communications Corporation's Petition to Deny, February 4, 2002, CS Docket No. 01-348.

⁴ Declaration of Walter L. Morgan in Support of Petition to Deny by the National Rural

Richard Gould (for NAB)⁵ and Roger Rusch (for Pegasus)⁶ and these will be referred to throughout this document as the “Morgan”, “Gould” and “Rusch” declarations respectively, or collectively as the “Petitioners”.

III. Trade-Off Between Local and National Programming

3. One common theme in the Morgan, Gould and Rusch declarations is the preoccupation with the provision of local programming at the expense of national programming. In practice EchoStar and DIRECTV must take into account both types of programming and strike the appropriate balance between them in offering a competitive service to the public.

4. In particular the two companies need to plan for the likely evolution of High-Definition TV (“HDTV”) to the point where it becomes an essential national programming product with vast audience appeal. The recent technical innovations and price reductions of large-screen TVs, and the corresponding increase in their sales, are clear indicators that the public is heading in the direction where its demands for HDTV will increase exponentially over the coming years. At present it is only possible to accommodate one HDTV channel in each 24 MHz satellite transponder, although it is possible that this could increase to two HDTV channels per transponder with further technical innovations.

Telecommunications Cooperative, Exhibit O of Petition.

⁵ Declaration of Richard G. Gould.

⁶ Affidavit and Report of Roger J. Rusch, Attachment B to Petition.

5. The increased requirement for transponder capacity capable of carrying national programming is not limited to HDTV. Other areas of growth in programming include new national networks and additional pay-per-view, video-on-demand, interactive and educational channels.

6. Therefore, EchoStar and DIRECTV must plan for a growth in requirements for transponders with the ability to provide national programming. The more of the scarce orbit-spectrum resource is used up for local programming the less is available to cater for this growth in national requirements. Each DBS operator has been licensed to use a limited amount of radio frequency spectrum and orbital slots and the operating companies must plan for the long-term. They must use their entire licensed spectrum as efficiently as possible, taking into account commercial realities and future growth in key areas of public demand.

IV. Spectrum Requirements for Local Programming

7. The essence of the Petitioners' technical arguments is their claim that the carriage of all of the local programming in all 210 DMAs in the United States by each DBS company is technically feasible in the absence of a merger. However, what might be technically feasible is not necessarily commercially reasonable because of important operational and economic factors. One of the key aspects of this determination is an understanding of the number of licensed DBS frequencies that will be used up by the local programming, and that issue is addressed in this section, and indirectly in the remainder of this Declaration.

8. The conclusions of the Petitioners are generally that all (or at least the vast majority) of the DMAs can be served with local programming (a total of around 1,500 TV channels) using an “acceptably” low number of DBS frequencies.⁷ Here is a summary of their claims in this respect:

9. NAB: Gould’s assessment is that DIRECTV and EchoStar would require between 17 and 19 DBS frequencies each for local programming (out of a total of 46 full-CONUS frequencies licensed to DIRECTV and 50 full-CONUS frequencies licensed to EchoStar). Although not absolutely clear in this regard, Gould appears to be suggesting that this would require new satellites that differ in design from the planned EchoStar and DIRECTV spot beam satellites already under construction (or already launched). Gould goes on to suggest that the number of DBS frequencies required for local programming (and national programming) could be reduced using improved compression, modulation, coding, etc, but he does not give the resulting number of DBS frequencies that would, in his estimation, be then required for the local programming.

10. NRTC: Morgan assumes for DIRECTV that both the DIRECTV 4S and DIRECTV 7S spot beam satellites will each use six DBS frequencies for local programming, and that this can be supplemented by a new satellite that would use a further three DBS frequencies, making a total of 15 DBS frequencies. With all these

⁷ These conclusions are neither correct nor appropriate, and more details on this are given in subsequent sections of this Declaration.

DBS frequencies Morgan predicts that 187 of the 210 DMAs can be served with local programming by DIRECTV.

11. For EchoStar, Morgan assumes that the EchoStar-7 and EchoStar-8 spot beam satellites will each use five DBS frequencies for local programming, and that this can also be supplemented by a new satellite that would use a further three DBS frequencies, making a total of 13 DBS frequencies. With all these frequencies Morgan predicts that 160 of the 210 DMAs can be served with local programming by EchoStar.

12. Pegasus: Rusch initially indicates that each company could serve all 210 DMAs with local programming using only 16 DBS frequencies each, using technology similar to their current spot beam satellites, although this assertion by Rusch is not backed up by any specific analysis. Obviously aware of the critical need to reduce this number of DBS frequencies allocated to local programming (approximately one third of each provider's full-CONUS DBS capacity), he then goes on to develop an alternate approach which involves discarding the planned spot beam satellites already under construction (or launched) and assuming each company builds a satellite along the lines of his "super-satellite" design. With this design Rusch claims that the number of DBS frequencies required by each company for local programming will reduce to 12. The technical failings of the Rusch "super-satellite" are discussed in detail in Section VII of this Declaration.

13. The Petitioners are generally correct in their understanding that the number of DBS frequencies that can economically be assigned by EchoStar and DIRECTV to

provide local programming must be minimized in order to keep it in economically reasonable proportion to the number of DBS frequencies available for national programming. However, there are at least two fundamental problems with their conclusions, as follows:

14. Problem #1: Where the Petitioners conclude that between 16 and 19 DBS frequencies should be allocated to local programming, these are still unacceptably high numbers in relation to the number of licensed full-CONUS frequencies available to each company (46 for DIRECTV and 50 for EchoStar). The remaining number of DBS frequencies available for national programming is insufficient for future growth in key areas of national programming that are and will become in demand. Furthermore, the costs to each company of operating so many local channels are excessive, as explained in the Declaration of Dr. Robert Willig which is also attached to Opposition of the Applicants.⁸ By contrast, after the merger, the allocation of 16-19 DBS frequencies to local programming out of a pool of 96 full-CONUS frequencies leaves adequate capacity for adding new national programming into the foreseeable future. The economic burden of operating this number of local channels is also reduced when carried by the merged company. See Declaration of Dr. Willig.

15. Problem #2: Where the Petitioners (Morgan and Rusch) propose exotic satellite designs to reduce the number of DBS frequencies consumed by local

⁸ See Declaration of Dr. Robert D. Willig on Behalf of EchoStar Communications Corporation, General Motors Corporation, and Hughes Electronics Corporation in CS Docket No. 01-358 (Feb. 25, 2002).

programming to what they consider to be an acceptable number (such as 12 in the case of Rusch), their satellite designs are simply not viable. The designs they propose are mere concepts, and rigorous analysis of their performance is distinctly lacking. Apart from this, the implementation of such satellite designs (if they were possible) would create huge technical risk, unacceptably long delays before they could ever be brought into service, and carry very high and unacceptable costs. These issues are dealt with in more detail in Section VII below.

V. Technical Factors Affecting Capacity

16. In order to attempt to “squeeze in” as many local TV channels as possible, the Petitioners rely in part on certain technical innovations, which are addressed in the sub-sections below. In each of these technological areas they take existing reality and hypothesize a development that is either inappropriate (for example, in terms of the quality of service to the public), impractical (for example, requiring expensive changeover of all subscribers to new set-top boxes), or just simply impossible (such as the claims of DMA coverage and service).

V.1 Compression

17. In the Joint Engineering Statement that was part of the Application it was stated that the normal compression ratio in use at that time was 10:1.⁹ This is the level of

⁹ This means that 10 TV channels can be combined and transmitted in digital format on a single 24 MHz bandwidth satellite transponder.

compression achievable today which provides minimally acceptable TV picture quality – compression levels above this start to show unacceptable “digital artifacts” which can be very distracting to the viewer.¹⁰ The extent of the manifestation of these digital artifacts depends on the combined amount of picture detail and movement that exists for all the combined TV channels at any point in time, and is very difficult, if not impossible, to quantify. For example, if situations arise in which a lot of detailed picture changes are occurring simultaneously in a number of the TV channels that are being combined, then some of those channels will start to show these artifacts, typically in the form of the jerky movement of picture blocks across the TV screen. Subjective tests have shown users to be very intolerant of these picture degradations, and they need to be avoided to the maximum extent, consistent with efficient use of the transponder bandwidth.

18. The Joint Engineering Statement went on to predict that, in the future, it is likely that this compression ratio might reach a level of 12:1, while still preserving acceptable picture quality. At the present time such performance is not possible for all types of TV programs, depending on their picture content. Despite this, both EchoStar and DIRECTV have been obliged to recently operate a small number of transponders carrying local TV channels with compression ratios up to 12:1. This has been necessary as a result of the need to comply with the SHVIA requirements for local TV carriage, and generally occurs in situations where it was necessary to put all the candidate TV channels

¹⁰ Recent upgrades to the software algorithms used by the compression systems did not achieve the anticipated levels of improvement expected. As a result, instead of achieving desirable video quality at 10:1 compression levels, the quality is only minimally acceptable. Based on these results, it is currently believed that the next major release of software algorithms will not afford

in a particular DMA into the same transponder. Neither EchoStar nor DIRECTV are satisfied with the resulting picture quality in these transponders as situations inevitably arise when the unwanted digital artifacts are apparent. In other words, operation at 12:1 compression ratio is an “evil necessity” in a small number of cases at the present time, and not a normal or desirable mode of operation.

19. Petitioners clearly are unaware of the variety of demands on the raw bandwidth of a DBS transponder. They have assumed higher compression ratios in their analysis than is currently achievable from an operational DBS system with real requirements and limitations if high picture quality is to be guaranteed. Gould states that *“The transponder capacity can be shown to be between 12 and 14 NTSC channels using standard methods of modulation.”*¹¹ Rusch states that *“... 12 television signals can be transmitted on each frequency block”*¹² Morgan states that his assumption in his analyses is *“... a video compression rate of 12:1.”*¹³ Their theoretical capacity estimates are grossly in error due to such optimistic assumptions about compression, as well as other erroneous assumptions addressed below.

20. For example, Petitioners appear to have ignored that fact that approximately 20% of the available bandwidth on every transponder in the network is needed for non-video purposes. The compression systems require available “headroom” bandwidth within the overall bit stream within every transponder. This bandwidth is

any additional channel capacity, instead affording the opportunity to restore quality to the normal levels the customers have come to expect.

¹¹ Gould Declaration, page 7.

necessary for the systems to perform their compression and multiplexing functions and is unavailable for use by the satellite provider. Many channels also broadcast an alternate language audio channel in addition to the primary language, in support of bilingual viewers. Additionally, Dolby Digital (an enhanced audio format) is broadcast as a secondary audio source on many DBS channels, and it alone is equivalent to two normal audio channels, bringing the total for those channels to three equivalent audio channels. Furthermore, every transponder carries a set of data tables necessary to communicate critical information from the uplink systems to the individual set top receivers. This information is needed by the receiver to be able to understand which satellite a given program is located on, which of the multiple data streams within the transponder contains the video, which audio streams are associated with the video, whether the customer has appropriate rights to the video, and a host of other details elemental to the operation of a digital video system.

21. Lastly, one transponder at every satellite location includes a complete Electronic Program Guide, as well as software downloads for every model of every receiver ever produced. One third of the available capacity of this “home” transponder is dedicated to supporting this application. As the size of the network and the number of customers grows, so does the bandwidth requirements on each and every transponder.

¹² Rusch Declaration, page 5.

¹³ Morgan Declaration, page 4.

V.2 Video Coding

22. Both Rusch and Gould make strong statements about the future use of MPEG-4 video coding in place of MPEG-2, suggesting that the change to this coding standard would make dramatic further reductions in the data rate required for broadcast quality video signals, and hence increase the number of TV signals per transponder. Gould states that *“Moreover, new generation algorithms such as MPEG-4 are being designed and implemented to provide even more digital compression than is available now with MPEG-2. With greater compression, the required data rates will decrease and the number of TV channels that can be supported on a single transponder will increase beyond the assumptions made above”*.¹⁴ Rusch states that *“For even greater gains, the recently adopted MPEG-4 standard can provide a reduction in data rates by a factor of two or three as compared to MPEG-2”*.¹⁵

23. These statements demonstrate a popular misconception about the role and applicability of MPEG-4 to broadcast quality video transmissions. The fact of the matter is that MPEG-4 is currently designed to allow more effective video bit-rate reductions only for signals of a much lower quality than are transmitted to the public by DBS satellites. Applications intending to exploit MPEG-4 are therefore ones where data rate is severely limited and quality considerations are of secondary importance, such as video streaming over the Internet. For the quality required for DBS satellite transmissions, which is effectively “broadcast quality,” MPEG-4 provides no reduction in required bit-

¹⁴ Gould Declaration, page 14.

¹⁵ Rusch Declaration, page 11, para. 39.

rate compared to MPEG-2, and therefore cannot seriously be considered at the present time for use by EchoStar or DIRECTV for their conventional broadcast services.¹⁶

24. Furthermore, the use of MPEG-2 allows for significant cost savings in manufacturing receivers as compared to MPEG-4 and has greater economies of scale due to its widespread use.

25. Finally, it should be noted that a transition to MPEG-4 would require all new set-top boxes, with negligible, if any, revenue or capacity benefit.¹⁷

V.3 Modulation and Coding

26. Currently both EchoStar and DIRECTV use QPSK for their satellite transmissions. This has been, and remains, the right choice from the point of view of spectral efficiency, satellite power requirements and ease of implementation in the user equipment.

27. However, Gould proposes that EchoStar and DIRECTV's current QPSK transmissions be replaced by 8PSK or even higher order modulation transmissions. Gould's justification for this is "*Modern spacecraft are capable of providing the greater power that is needed in order to achieve the higher spectral efficiency afforded by 8PSK*

¹⁶ There are long-term developments aimed at achieving broadcast quality encoding at 1 MBit/sec but it is not certain whether this will be MPEG-4 or a new evolving standard called H26L. Neither format is yet suitable to achieve such a low bit rate consistent with reasonable quality. At bit rates of 2 MBits/sec and higher there is very little difference in terms of picture quality between MPEG-2 and MPEG-4.

¹⁷ Transition issues where new set-top boxes are required are addressed in Section V.3.

modulation discussed earlier, and by other, higher-order, modulation methods ...”.¹⁸

Rusch similarly proposes the change from QPSK to 8PSK, also citing the relative ease of generating additional power on the satellite as justification. Such comments, however, ignore the fact that satellite power is always at a premium, and therefore its efficient use cannot be so easily dismissed as Gould and Rusch have done. The requirement to generate between 30% and 50% more RF power, as might be required for the use of 8PSK, could have the effect of increasing the satellite platform DC power requirements from typically 10 kW to between 13 and 15 kW. Such an increase would have considerable impact on the satellite and launch vehicle costs, and reduce the scope of potential spacecraft suppliers and platform products.

28. Both Gould and Rusch separately promote a change in the coding of the EchoStar and DIRECTV transmissions to make use of the latest turbo coding techniques. However, Rusch in particular creates a false impression here that turbo coding, in and of itself, will make dramatic improvements to the spectral efficiency of the DBS satellites. He states *“One method of increasing channel capacity or throughput is called turbo coding. This method is currently being used on some satellite services to improve the signal robustness (lowering the required Eb/No) substantially, by as much as a factor of two. This could double the effective channel capacity.”*¹⁹ This proposed doubling of the channel capacity by the use of turbo coding is simply not the case when applied to the existing satellite transmissions used by EchoStar and DIRECTV, because of the coding

¹⁸ Gould Declaration, page 13.

¹⁹ Rusch Declaration, page 10, para. 35.

levels already in use. Turbo coding merely improves the signal's robustness without as much coding overhead as would be required with conventional coding. It does not affect the spectral efficiency directly.

29. While the combined use of 8PSK and turbo coding might be an attractive alternative to QPSK and conventional coding for new systems, and result in an overall spectral efficiency improvement on the order of 30%, depending on the conventional and turbo coding levels employed, further tests are necessary before it can be confirmed that the existing satellite transponder frequency response and linearity specifications are sufficient for this new modulation and coding scheme. Operation in a self-interference environment, such as a spot-beam satellite where spatial frequency re-use is employed between multiple spot beams, also needs to be investigated further before such a new scheme can be relied upon. In the context of EchoStar and DIRECTV's current operations, however, any such change would require new (and more expensive) set-top boxes for all subscribers if it were to be applied to both the local and national programming channels. Evolutionary transition schemes, as suggested by Rusch, will only address a relatively small percentage of the subscribers.²⁰ At some point in time, the entire population of viewers must get new set-top boxes installed before the main (national) channels in the system are transitioned to the new modulation and coding scheme.

²⁰ Rusch Declaration, page 11, para. 39.

V.4 Administrative Channels

30. In assessing the TV channel capacity of the EchoStar and DIRECTV satellite systems, it is important to note that some channels are required to carry “administrative” information and data to the subscribers. Not all “available” channel capacity can be used to transmit revenue-generating TV programs. The administrative channels are used for “TV Guide” information as well as data communications to the subscribers’ set-top boxes. This matter is also addressed in Section V.1 above.

V.5 Beam Coverage and Effect on Capacity

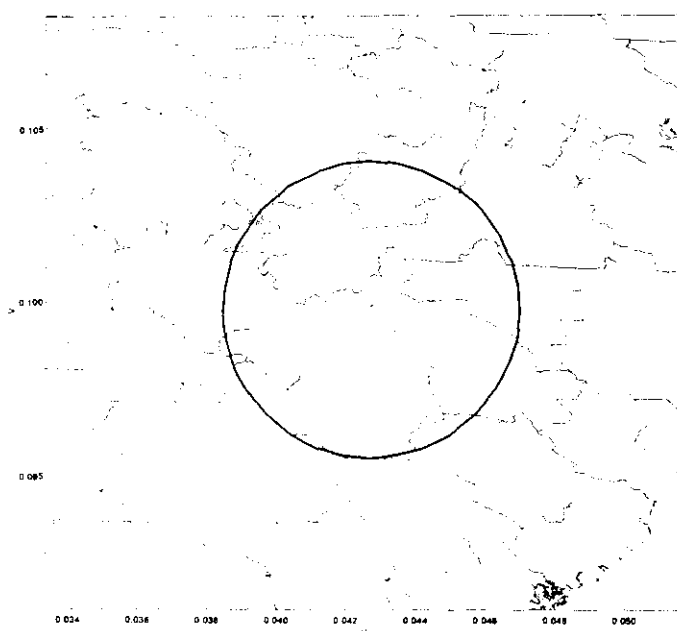
31. All of the Petitioners, either directly or indirectly, make assumptions about the spot beam coverage of the satellites. In the case of Morgan, he addresses both the existing (and under construction) satellites, as well as his proposed additional spot beam satellites. In the case of Rusch and Gould, they address only new satellite designs. The spot beam coverage of these satellites is the key to determining their capacity, in terms of local TV channels in the various DMAs. None of the Petitioners has adequately addressed this issue in their technical submissions.

32. Designing the beam coverage for local programming to the defined DMAs is a very challenging exercise. The DMAs are not conveniently sized or located in a way that is amenable to optimum coverage by satellite. Inevitably, compromises have to be made, and the resulting performance, in terms of the number of DMAs served, falls far short of the ideal. There are several reasons for this, as follows:

33. DMA size and shape: The DMAs vary widely in their geographic

size, depending on their population densities, and they are irregularly shaped (see Figure 1 below). By contrast the easiest spot beams to generate, from the satellite design and performance perspective, are ones that are circular as viewed from the satellite. There are also severe limitations on how small the spot beams can be made, and it is preferable by far to maintain a constant, or near-constant, spot beam size if possible. The inevitable result of all these constraints is that spot beams on DBS satellites are made to be relatively large compared to the smaller DMAs, and therefore each one encompasses several DMAs, or at least parts of several DMAs. The beams are also often too small to encompass the largest DMAs. In the example shown in Figure 1 the spot beam is the -3 dB contour of a beam generated with a 3 meter satellite antenna reflector. Note that it covers two adjacent DMAs completely, but only parts of some other DMAs in the vicinity.

Figure 1: Example of DMAs in Eastern part of the USA



34. Relative priority and geographic location of the DMAs: To re-use the same frequencies between spot beams requires that those spot beams are spaced a certain distance apart. Unfortunately, the DMAs to be given higher priority for coverage are not conveniently spaced the required distance apart, and so the ideal frequency re-use cannot be achieved.

35. Numbers of local TV channels to be carried for each DMA: There are a certain number of TV stations associated with each DMA and all of these are potential candidates for carriage under SHVIA rules if any one of them is carried. Therefore it is necessary to serve, within a single beam, an aggregate number of channels that just fills the allocated number of transponders (e.g., one or two per beam). This may mean that, although a beam provides coverage of a particular DMA, there may be insufficient capacity in the allotted number of transponders to actually provide service to all of the TV channels required by that DMA. In that case, the DMA cannot be served at all by that beam.

VI. Capability of EchoStar and DIRECTV Satellites Already Launched or Under Construction

36. In this section I address the claims made by Morgan concerning the amount of local programming that could be carried with the four spot beam satellites already launched or under construction by EchoStar and DIRECTV.^{21,22}

²¹ These spot beams satellites are EchoStar-7, EchoStar-8, DIRECTV D4S and DIRECTV D7S.

²² Only Morgan provides an analysis of the number of local TV stations (and DMAs) that he believes

37. In the time available since the Petitions were filed with the FCC it has not been possible to replicate the detailed analysis presented by Morgan. Although Morgan has endeavoured to describe an objective methodology for his analysis, he admits that certain of his steps involved him making subjective determinations. For example, he states that “... *the assignment (if capacity was available) was made in concert with the other demands in each beam ...*”²³, but he doesn’t define what those demands are. Elsewhere he states “... *I made educated decisions as to how the beams and frequencies could be used ...*”²⁴. Therefore, Morgan’s results cannot necessarily be replicated without full knowledge of some of the decisions he was forced to make as he progressed in his analysis. But more importantly, Morgan’s results cannot be completely accurate as he made certain assumptions that are not consistent with the actual design of the spot beam satellites. For example, he assumed that DIRECTV 7S would use six DBS frequencies for local spot beam service whereas in fact it is designed to use only four DBS frequencies.

38. Despite the inevitable inaccuracies in Morgan’s analysis, his conclusions, in terms of the combined capacity of the DIRECTV 4S and DIRECTV 7S spot beam satellites, are relatively accurate. However, in the case of the EchoStar-7 and EchoStar-8 spot beam satellites, his conclusions regarding local channel capacity are considerably

could be carried by the existing spot beam satellites (including those under construction). Rusch and Gould both hypothesize only about future new satellite designs when addressing overall local TV channel capacity.

²³ Morgan Declaration, page 9.

²⁴ Morgan Declaration, page 11.

higher than the actual satellites are known to be capable of, and the reasons for this are not yet clear.

39. In any event, when Morgan proceeds beyond estimating the capacity of the current satellites, he makes assumptions that are seriously in error. These relate to the design of his additional satellite, which he assumes would require only three additional DBS frequencies (see more details of this in Section VII below). He claims, for example, that the three additional DBS frequencies on his third satellite for DIRECTV can be used, in conjunction with DIRECTV 4S and DIRECTV 7S, to provide full local programming service to a total of 187 DMAs.

40. It should also be pointed out that Morgan's analysis is based only on considerations of the available spectrum, and it does not consider in any way the important economic factors that are relevant to the provision of local TV service in the different DMAs. This is in fact one of the main drivers in deciding which DMAs can be served, and is addressed in the Declaration of Dr. Willig.

VII. Potential New Satellite Designs Proposed by Petitioners

41. All three Petitioners propose, in one way or another, new satellite designs that they claim will enable the full complement of DMAs to be served. Each Petitioner takes a different approach to this problem:

42. Gould: Although Gould does not provide details of a new satellite design, his argument is essentially that the available spectrum could be used, with a

suitable new satellite design, and other changes to the system, to serve all 210 DMAs. Because of his lack of specific design detail he is forced to estimate the capacity of the new satellite by using capacity related parameters derived from the design of the existing (and under construction) spot beam satellites. In this regard, he assumes that the average frequency re-use of the spot beams, for all 210 DMAs, is 7.33.²⁵ This level of re-use is derived from the DIRECTV 4S satellite design, which serves only 41 DMAs. This same level of re-use cannot be maintained if more DMAs are served by adding spot beams because, as indicated above, the DMAs are not conveniently located or sized to suit the spot beam re-use pattern. Therefore the average frequency re-use will become progressively less as more spot beams are added and more DMAs are served. Without going through a detailed and complex spot beam satellite design exercise it is impossible to quantify what average frequency-re-use factor could be achieved.

43. Rusch: Rusch proposes a single dedicated local TV broadcast satellite that employs 58 spot beams (16 large and 42 small), with 12 transponder frequencies in use and an average of 9.33 times frequency re-use to achieve a total capacity, using 8PSK modulation, of 1792 TV channels. This number of channels is presumed to be sufficient to provide the 1475 local TV channels to the 210 DMAs allowing for the DMA “edge effects”.²⁶ This new satellite is presumed to replace the

²⁵ In fact, Gould states on page 4 of his Declaration that the frequency re-use could be as high as 10 or greater. There is no basis for such an assertion, and the exercise of going through the detailed design of a spot beam satellite for service to all of the DMAs would demonstrate that such a high level of average frequency re-use is far from achievable.

²⁶ Rusch uses the term “edge effects” to describe the fact that the available channels do not fit conveniently into transponders to achieve the required number of channels in the required beam for the DMAs. Rusch assumes that a factor of 20% is sufficient for these “edge effects”, but there is

existing spot beam satellites already launched or under construction. Because of the use of two sizes of spot beams on this new satellite, and the inevitable self-interference between them, an interference cancellation technique is proposed. To reduce the number of uplink sites to six the system uses on-board processing. This design is not viable for a number of reasons, which are addressed in detail in the following sub-sections.

44. Morgan: Morgan proposes that each company should build another spot-beam satellite that complements its existing (and soon to be launched) spot beam satellites in order to provide local TV service to additional DMAs. In the case of DIRECTV the total number of DMAs that Morgan asserts could then be served would be 187, and for EchoStar the number is 160. These new satellites each use only three additional DBS frequencies, and either 50 beams (EchoStar) or 46 beams (DIRECTV). They are intended to achieve a high level of frequency re-use (17:1 for EchoStar and 15:1 for DIRECTV). Again, such a design is not viable for the reasons noted in the following sub-sections.

VII.1 Specific Technical Problems with the Proposed Designs

45. In this section I will explain why the proposed new satellite designs of Rusch and Morgan are flawed, and the performance levels claimed could never be achieved in practice. These proposed designs are concepts only – they have not been through the scrutiny of a real design by companies that manufacture satellites - and we are

no basis for this number. In practice the factor may need to be much greater than 20%, depending on the specifics of the design.

confident that if these designs were ever explored in detail with a view to actual implementation then their predicted performance levels (or even feasibility) would change dramatically.

VII.1.1 Realization of the Spot Beams

46. Rusch proposes spot beams that are significantly smaller than those used on any of the DIRECTV or EchoStar spot beam satellites. The smaller the spot beams the larger the antenna reflectors on the satellite, and Rusch states that his design requires a 6 meter reflector. This compares with the antenna reflectors on the existing (and under construction) DIRECTV and EchoStar spot beam satellites, which have maximum antenna reflector dimensions as follows:

DIRECTV 4S:	2.8 meters
DIRECTV 7S:	3.5 meters
EchoStar-7:	2.7 meters
EchoStar-8:	2.8 meters

47. Accommodation of the antenna reflectors on the satellite is a major driver in the overall satellite design. Large reflectors can be very difficult to accommodate within the physical envelope of the launch vehicle, and create other stability problems for the satellite's attitude control system. Although larger antenna reflectors have been used on some commercial satellites (e.g., ACeS, Thuraya), these satellites have operated at much lower frequencies where unfurlable mesh antennas can be used. At the Ku-band frequencies used for DBS by EchoStar and DIRECTV the satellite antenna reflectors

must be solid surfaced reflectors, and so accommodation of reflectors larger than about 3.5 meters requires breaking the reflector into smaller pieces that are then hinged together. Such an approach is expensive, high-risk, and suffers poor sidelobe performance. The latter problem is particularly important for a multi-beam design with spatial frequency re-use, as it increases the self-interference within the system.

48. Not only is the size of an individual satellite antenna reflector of critical importance, but the number of such reflectors is equally important. The more large reflectors there are on the satellite the greater the problems in configuring them in a manner that orientates them in the right directions relative to the feed positions, not to mention the additional antenna stowage and deployment problems. Both the Rusch and Morgan designs are based on an array of contiguous beams, and such an approach requires multiple reflectors in order to achieve the sidelobe performance necessary to reduce self-interference (from co-frequency, spatially separated beams) to an acceptable level. Typically, in these designs, the geographically adjacent beams will not be generated from the same antenna reflector, as otherwise the antenna feed performance has to be compromised and the sidelobe performance suffers. Therefore, a contiguous spot beam design will require at least three reflectors to generate an array of high performance beams. In the case of the Rusch design this number could be as high as six reflectors, because of the use of two different sizes of beams. In this case three smaller reflectors would be needed to generate the array of larger beams.

49. In conclusion, the antennas required in the Morgan and Rusch satellite designs could not be accommodated on a single spacecraft. No commercial satellites

have been flown with such large numbers of large solid reflectors operating at Ku-band frequencies. The Petitioners do not seem to have given any consideration to this fundamental failing in their designs.

50. Another problem that is exacerbated by the use of smaller beams, as is used in the Rusch designs, is the antenna pointing error. All satellite antennas are subject to pseudo random pointing errors and perturbations. On large beams the effect of this mispointing is insignificant. However, as the beam size becomes smaller, the relative effect of the mispointing increases. In the case of a 0.3° spot beam, as proposed by Rusch, the typical pointing error could be typically 0.12° , which means the beams may be pointing anywhere within 0.12° of the nominal pointing direction.²⁷ This has the effect of reducing the guaranteed service area of the beam to only 0.06° (i.e., 0.3° minus $2 \times 0.12^\circ$). In other words the useful beam area becomes exceedingly small and effectively useless for a local programming type of service.²⁸ Furthermore, the antenna pointing error will cause increased interference between spatially separated beams, if they are generated by different antenna reflectors that are prone to uncorrelated pointing errors. In this case, a co-frequency beam would appear to be closer to another beam operating at the same frequency than the nominal pointing directions would indicate, and the self-

²⁷ This amount of pointing error is typical of open-loop designs. If sophisticated closed-loop RF sensing is employed, the pointing error could be reduced to 0.05° , but this performance would be very difficult, if not impossible, to maintain across the whole array of spot beams.

²⁸ For DBS the users are stationary and the satellite beams are assumed to be stationary. Only in this way can a subscriber's receiver rely on receiving signals according to a fixed frequency plan. This is very different from, for example, an MSS (Mobile Satellite Service) system, such as ACeS, Thuraya, GlobalStar or Iridium, where the users are assumed to be moving across the boundaries between beams, and the transmission scheme and frequency plan allows for the subscriber terminal to be frequency agile and capable of switching seamlessly between beams.

interference would be correspondingly increased. Again, neither Rusch nor Morgan even mention antenna pointing errors in relation to their proposed designs for new spot beam satellites. In particular, Morgan has ignored these effects when calculating the DMAs served by his spot beam design.

VII.1.2 Self-Interference

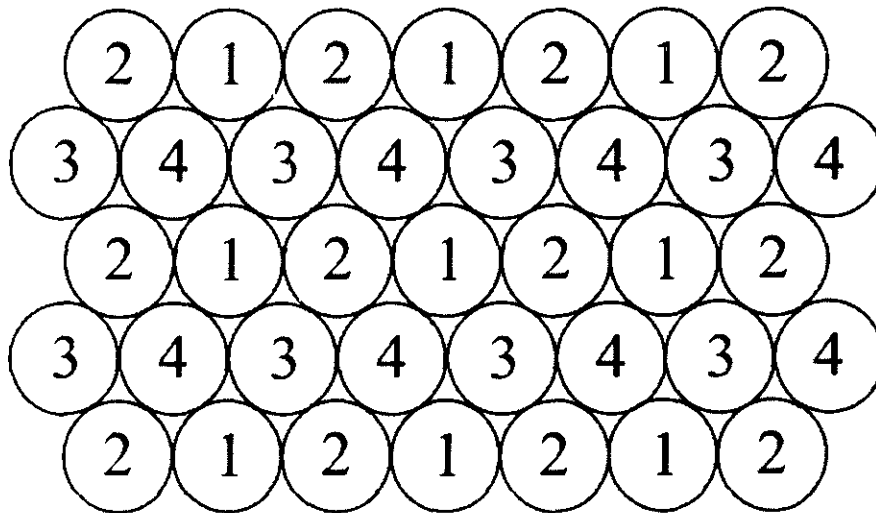
51. Whenever frequency re-use is employed in a satellite there is the potential for self-interference. The higher the amount of frequency re-use the greater the risk of unacceptable levels of self-interference. This is particularly important if higher order modulation schemes (such as 8PSK or higher) are to be employed in the system, as these require higher $C/(N+I)$ (carrier to noise+interference ratio) performance than if conventional QPSK is used.

52. In a spot beam satellite design, where spatial frequency re-use is employed (as is the case with the EchoStar and DIRECTV spot beam satellites as well as the Rusch and Morgan designs), great care must be taken to ensure that the co-frequency beams are sufficiently far apart that they do not interfere with each other. When the spot beams are a contiguous array, as in the case of both the Rusch and Morgan designs, a frequency re-use scheme must be established that avoids co-frequency operation in immediately adjacent beams.

53. Rusch employs a four-frequency group scheme, which means that the available spectrum is divided (not necessarily equally) into four parts, and each part is then assigned to one of a set of four contiguous beams. This same assignment is then

continued across the whole array of beams to ensure that the maximum beam isolation is achieved. This is shown in Figure 2 where a section of an infinite array of beams operating with a four-frequency group scheme is shown. (Note the proximity of the nearest co-frequency beam is one complete beamwidth away and that there are four co-frequency beams that are this same distance away.) All these beams, as well as those further away, contribute to the interference experienced in the center beam. To maintain the aggregate interference to an acceptably low level, the sidelobes of these co-frequency beams must be maintained to a very low level in the directions of the center beam (as well as other co-frequency beams).

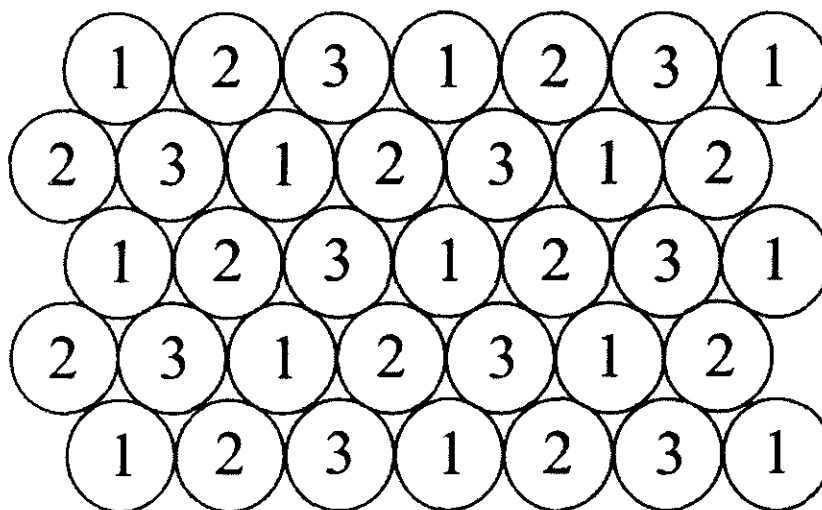
Figure 2: Four-Frequency Group Re-Use Scheme



54. Morgan, on the other hand, uses an even more aggressive approach, presumably to keep the number of channels used by his spot beam satellite design to only three. In his design, a three-frequency group scheme is used, as shown in Figure 3. Note

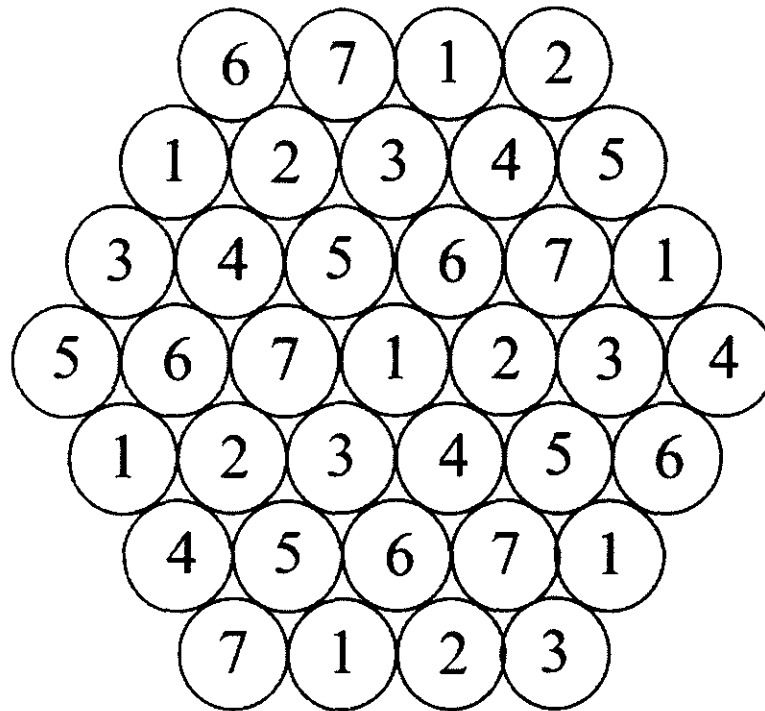
that with this scheme the nearest co-frequency beam is now closer than it was with Rusch's design, and there are now six co-frequency beams spaced this same distance away. The result of this is that the self-interference levels are even higher with this three-frequency scheme than with the four-frequency scheme.

Figure 3: Three-Frequency Group Re-Use Scheme



55. Experience in the design of spot beam satellites, however, has shown that the theoretical four-frequency and three-frequency re-use schemes are impractical in many cases because the aggregate self-interference is unacceptably high. Instead system designers have resorted to schemes with less spatial re-use, such as seven-frequency re-use schemes. Such a scheme is shown in Figure 4. Note that the nearest co-frequency beam is almost two full beamwidths away and there are still only six such beams in the immediate vicinity. The self-interference with a scheme like this is much less than with the three or four-frequency schemes proposed by Morgan and Rusch.

Figure 4: Seven-Frequency Group Re-Use Scheme



56. Therefore it is extremely unlikely that the spot beam designs and frequency re-use schemes proposed by Rusch and Morgan will work in practice, as they would exhibit extremely high self-interference levels. As mentioned above, high self-interference is incompatible with the use of high order modulation schemes (such as 8PSK and higher) as proposed by Rusch, Morgan and Gould.

57. Finally, the self-interference problem is made much worse when a mix of spot beam sizes is employed, as proposed by Rusch. In these cases the small spot beams suffer greater interference from the large spot beams unless they are given additional geographic separation. The Rusch design does not provide this additional separation, but rather resorts to a flawed interference cancellation technique that is addressed in the next

section.

VII.1.3 Interference Cancellation

58. Rusch rightly points out that his mix of large and small spot beams, in a contiguous spot beam array, will result in unacceptable levels of self-interference. To overcome this problem Rusch proposes the use of “... *an accepted technique known as “signal nulling” or “signal cancellation.” This technique involves deliberate (directional) coupling of a small part of the signal from the interference beam into a beam location where the interference would otherwise occur. Since the same signal appears in two beams, a user on Earth receives the same signal from two sources.*”²⁹ Unfortunately, this scheme will simply not work.

59. The interference cancellation technique proposed by Rusch is not an “accepted technique” in any sense, at least in the commercial satellite world. It has never been employed in direct broadcast TV satellites. It may have limited applications in very specialized government satellite systems, but it cannot produce interference-free operation across the service area of the beam. At best it will cancel the interference over a relatively small swath of the beam, but it will in fact increase the interference in other parts of the beam.

VII.1.4 Frequency Re-Use Factor

60. A high frequency re-use factor in a spot beam satellite is the key to

maximizing the capacity with the minimum usage of spectrum. EchoStar-7 re-uses the same frequencies five times in its spot beam design. DIRECTV 4S re-uses the frequencies an average of 7.33 times across its beams. Both Rusch and Morgan push this parameter to impractical levels, taking into account the DMA service areas and necessary spot beam characteristics. Rusch proposes a re-use factor of 9.33 and Morgan proposes a re-use factor of 15 times for his DIRECTV design and 17 times for his EchoStar design. In reality, the ability to achieve a high frequency re-use factor is constrained by practical limitations on the design and layout of the spot beams and how this relates to acceptable levels of self-interference, and this is addressed in more detail in Sections V.5 and VII.1.2.

61. Neither of these Petitioners shows the necessary justification to support such high frequency re-use factors. To adequately do this they would have to demonstrate that the levels of self-interference are at an acceptably low level, taking account of realistic antenna sidelobe performance and antenna pointing errors, as well as the actual antenna configurations that they propose (single or multiple reflectors, reflector mountings, etc). Without this their claims of frequency re-use are baseless.

VII.1.5 On-Board Processor

62. Rusch proposes the use of an on-board processor with at least 71 active 16-QAM on-board demodulators, each operating at approximately 100 Mbits/sec. This

²⁹ Rusch Declaration, Exhibit C, page 16, para. 27.

would be the first direct broadcast satellite to employ such a device, and would be a huge technological step for this type of application.

63. Although on board processing is technically feasible, the inclusion of an on-board processor of the type described by Rusch would negatively impact a satellite project in the following ways:

- High development, manufacturing and testing costs, probably in excess of \$50 to \$100 million, and possibly much more;
- Long program schedule, adding at least two years to the normal satellite schedule, and possibly more;
- Large demands on the spacecraft platform (or “bus”). The on-board processor would be large, heavy, consume significant electrical power and dissipate large quantities of heat. All of these factors will place additional demands on the spacecraft platform, and lead to a very large and expensive satellite;
- High risk. Such a crucial item of equipment could result in a catastrophic failure of the satellite if it should fail. Such a risk is significant and likely to be unacceptable to a DBS operator.

64. Rusch’s claims that *“Implementation of a full local-into-local service would require two or three years for design, construction and launch of appropriate new satellites”*³⁰ is therefore completely incompatible with his proposal to include the on-board processor that he describes.

³⁰ Rusch Declaration, page 8, para. 23.

VII.1.6 Payload Capability of Currently Available Spacecraft Platforms

65. Rusch implies that his “1475” design can be accommodated on a readily available spacecraft platform, but no evidence is presented to support this point. Based on my initial calculations, using the limited amount of information available concerning Rusch’s design, it far exceeds the payload capability of current platforms, and therefore would require the development of a large new spacecraft.

66. Morgan does not present any evidence to demonstrate that his design will fit onto any available spacecraft.

VII.2 Unacceptable Technical Risk

67. The satellite design proposed by Rusch is too complex and requires significant advances in the state of the art for operators such as EchoStar and DIRECTV to consider using. Its novel on-board processor and interference cancellation techniques are fraught with potential problems, including high costs, long program schedules, and the risk that they will not work. The spot beam design has not been shown by Rusch to be viable in terms of self-interference, or the ability to actually serve the territories of the DMAs with the TV channel capacities required.

68. The additional technical risk introduced by Rusch’s design also would severely impact the insurability of the satellite, or result in insurance costs that are commercially unacceptable.

VII.3 Delayed Schedule for Implementation

69. As mentioned in Section VII.1.5 above, Rusch's claims that *"Implementation of a full local-into-local service would require two or three years for design, construction and launch of appropriate new satellites"* is not consistent with the satellite design that he suggests. If the satellite he suggests were to be designed and built, it would likely be between four and five years, if not more, before service could begin once a decision to proceed was made. This assumes that ways could be found to overcome the technical problems in his design that are addressed in Section VII.1 above.

70. Such an extended schedule is incompatible with the objectives of EchoStar and DIRECTV, which is to provide high quality programming and a range of TV broadcast services to the public in a timely manner.

VII.4 Unacceptable Costs

71. Rusch's claims that *"The new satellites would cost approximately \$250 million each (satellite, launch vehicle and insurance). In addition, there would be the need for four-to six additional uplink Earth stations that should cost approximately \$30 million in total capital costs"*,³¹ This estimate is much too low for the system design he proposes. In particular:

- A satellite with on-board processing, and the antenna configuration required for his proposed spot beam design, would likely cost in excess of \$400 million; and

- The additional uplink earth stations, and associated ground equipment for the off-air reception and backhaul of the local TV channels, would likely cost in excess of \$100 million, taking into account the transition to 8PSK and the higher levels of compression.

72. Furthermore, it should be noted that both EchoStar and DIRECTV have already committed to building and launching their spot beam satellites, and these costs cannot be recouped. These entire investments would be wasted if the companies were to attempt to build the proposed Rusch satellite design. Rusch suggests that the existing EchoStar and DIRECTV spot beam satellites that have not yet been launched could be modified to achieve the capability of his proposed new satellite, and states that “*We would estimate that these modifications would require no more than 18 months and cost \$10-\$20 million*”.³² Although difficult to quantify at this stage, bearing in mind the advanced stage of construction and testing of EchoStar-8, Rusch’s number is a gross underestimate, and the likely cost, if it were even feasible, would be in excess of several hundreds of millions of dollars per satellite. The schedule impact would also likely be well in excess of 2 years.

³¹ Rusch Declaration, page 8, para. 23.

³² Rusch Declaration, page 8, para. 24.

CERTIFICATION OF PERSON RESPONSIBLE
FOR PREPARING ENGINEERING INFORMATION

I hereby declare under penalty of perjury that I am the technically qualified person responsible for preparation of the engineering information contained in the foregoing submission, that I am familiar with Part 25 of the Commission's rules, that I have either prepared or reviewed the engineering information submitted in this pleading, and that it is true and correct to the best of my knowledge and belief.

A handwritten signature in cursive script, reading "Richard Barnett", written in black ink.

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Dated: February 25, 2002

Resumé for Dr. Richard J. Barnett

Dr. Barnett graduated from Southampton University (UK) in 1973 with a B.Sc. (Hons) degree in Electronic Engineering, and from the same university in 1977 with a Ph.D. degree based on research into computer modeling of microwave devices.

He then worked in the research and development laboratories of the Plessey Company and the Independent Broadcasting Authority in the UK before moving to France in 1981. There he was employed by Thomson-CSF in Paris as the payload systems engineer on the Scandinavian Tele-X satellite before joining EUTELSAT where, as operations engineer, he was responsible for the operational planning of the EUTELSAT satellites for all TV applications.

In 1982 he returned to the UK and joined British Aerospace where he held a variety of engineering management positions during the period 1982 to 1990, all involved with the communications engineering and associated regulatory aspects for future commercial satellite communications projects. Dr. Barnett came to the USA in 1990 as the Vice President of Engineering for Asia Pacific Space & Communications (a company affiliated to Orion Satellite Corporation).

Since 1991 Dr. Barnett has been President of Telecomm Strategies LLC - an international satellite communications consultancy company specializing in the technical design and technical regulatory aspects of satellite projects including national licensing and international (ITU) frequency registration and coordination of satellite systems. In the domestic US arena he has chaired several US industry working groups that have developed consensus positions relating to Ka-band GSO/FSS, including the 1st round Ka-band orbital assignment plan, Ka-band blanket licensing rules and the preparation of US ITU filings for Ka-band and V-band satellite networks. In the ITU forum he is a participant in the groups related to satellite communications, particularly Working Party 6S and Working Party 4A, as well as the World Radio Conferences. He regularly participates in international frequency coordination meetings on behalf of various satellite operators, involving systems at S, C, X, Ku and Ka-bands.